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METHANOL FROM WOOD WASTE: A TECHNICAL AND ECONOMIC
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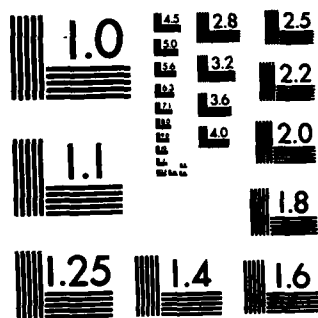
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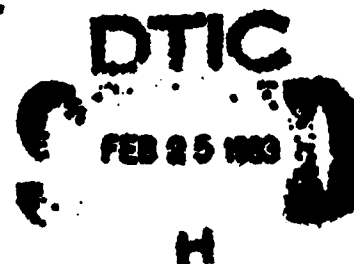
METHANOL FROM WOOD WASTE:
A Technical and Economic Study

By

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and
R. M. ROWELL

June 1977

Forest Products Laboratory
Forest Service
U. S. Department of Agriculture



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ABSTRACT

→ A methanol-from-wood waste facility having a capacity of 50 million gallons per year requires 1,500 oven-dry tons (ODT) of wood waste per day. The yield of methanol from wood is about 38 percent, or about 100 gallons per ODT of wood. This yield is based on all process energy required coming from the wood waste. At a wood waste cost of \$15/ODT, the selling price of methanol is estimated at \$0.77/gal; at \$34/ODT, the selling price is \$0.96/gal. ←

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METHANOL FROM WOOD WASTE: A TECHNICAL AND ECONOMIC STUDY

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INTRODUCTION

To reduce petroleum consumption in the United States, one proposal is to blend 10 to 15 percent of methyl alcohol (methanol) in gasoline for automotive use.^{2/} At a current consumption rate of 110 billion gallons per year (gpy), 11 billion gallons of methanol would be required. At present, methanol capacity in the United States totals 1.2 billion gpy, of which 99 percent is petroleum-derived, either from natural gas or from refinery light-gas streams. To increase methanol production, recommendations have been made to use other sources of carbon for synthesis of methanol. The Forest Service, in cooperation with the National Science Foundation, and the Federal Energy Administration, conducted a technical and economic feasibility study for producing methanol from wood waste.

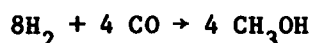
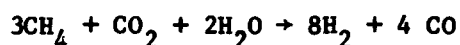
Methanol Production Today

Methanol is produced synthetically from carbon monoxide (CO) and hydrogen (H₂). In a catalyst-filled converter operating at pressures ranging

^{1/} Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

^{2/} Reed, T. B., and R. M. Lerner. 1973. Methanol: A versatile fuel for immediate use. Sci. 182 (4119):1299-1304. (Dec. 28.)

from 1,500 to 4,000 pounds per square inch (lb/in.²), two volumes of hydrogen to one volume of carbon monoxide react to form a crude methanol which is refined. In today's methanol plants, natural gas, consisting primarily of methane, is steam-reformed catalytically into CO and H₂. A small amount of carbon dioxide is added to the methane to permit part of the hydrogen to form additional CO so that the final gas product contains two volumes of H₂ to one volume of CO. These reactions are:



Methanol From Wood Waste

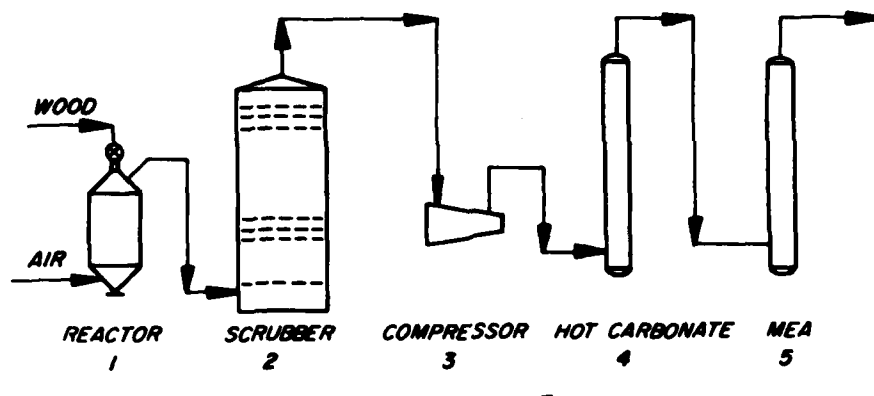
Any carbonaceous material such as coal, lignite, wood waste, agricultural residue, and garbage can be utilized for synthetic methanol production. However, in contrast to natural gas, these raw materials require several additional processing steps to refine the crude gas product into a final clean gas product (syngas) consisting of two parts of H₂ to one part of CO.

As a result, the conversion of a carbonaceous material is considerably more energy-intensive than that required by natural gas. Its logistics are considerably greater (solids handling vs. pipeline). Its yield is less. A schematic drawing of the overall process steps for converting wood waste into methanol is shown in figure 1.

GASIFIERS

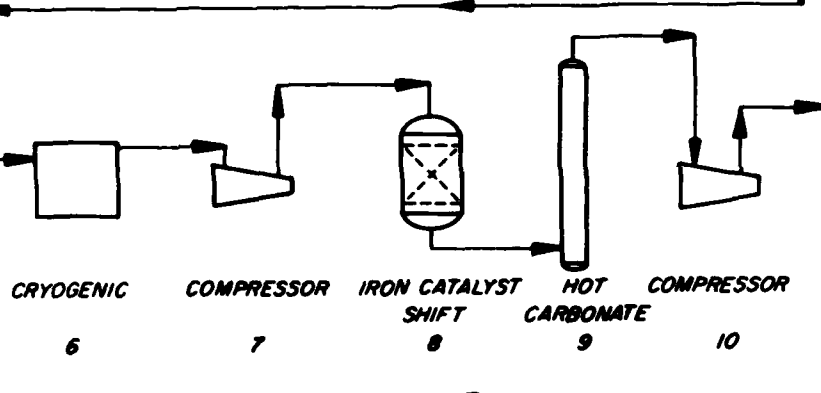
For any solid carbonaceous material to be converted into a syngas, it is first necessary to partially burn or oxidize the material to produce a crude gas consisting primarily of H₂, CO, and CO₂. If air is used to oxidize the feed material, the crude gas contains about 46 percent nitrogen, which can be removed by cryogenic means. If oxygen is used instead of air, a cryogenic system is required for initial separation of air into oxygen and nitrogen.

Several types of gasifiers have been developed for the partial oxidation of wood, wood waste, and garbage. These are designed to operate at atmospheric pressure, in contrast to coal gasifiers which can operate at pressures up to 400 lb/in.². Gasifiers produce a crude gas consisting primarily of H₂, CO, and CO₂ with minor amounts of heavier hydrocarbons. Also, about 2 percent of the wood (dry basis) is converted to an oil-tar fraction. A comparison of the crude gas from two types of gasifiers is shown in table 1.

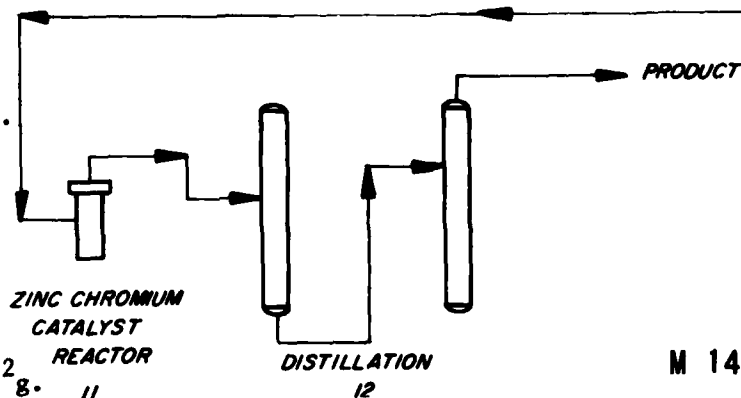


Process Steps

1. Partial oxidation of wood waste.
2. Clean and cool crude gas.
3. Compress to 100 lb/in.² g.
4. Remove carbon dioxide.
5. Remove residual carbon dioxide.



6. Remove nitrogen and hydrocarbons.
7. Compress to 400 lb/in.² g.
8. Shift gas to two parts hydrogen and one part carbon monoxide.
9. Remove carbon dioxide formed in shift.
10. Compress to 2,500 lb/in.² g.



11. Convert hydrogen and carbon monoxide into methanol.
12. Refine crude methanol into specification grade product.

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Figure 1.--Methanol synthesis from wood waste.

Table 1.--Comparative crude gas compositions

Raw gas (dry basis)	Moore-Canada (wood waste)	UCC Purox (garbage)
	<u>Vol. in pct</u>	<u>Vol. in pct</u>
Hydrogen	18.3	26.0
Carbon monoxide	22.8	40.0
Carbon dioxide	9.2	23.0
Methane	2.5	5.0
Hydrocarbon	0.9	5.0
Oxygen	0.5	0.5
Nitrogen	45.8	0.5
	100.0	100.0

Although the feed material for the UCC Purox reactor is garbage, it is expected that the crude gas composition will be essentially the same for wood waste because garbage has been found to have practically the same composition with regard to carbon, hydrogen, and oxygen.

Purox

Under the name "Purox," Union Carbide has developed a process for the partial oxidation of "as-is" garbage using oxygen^{3/}. The reactor-gasifier employs a moving bed in which oxygen is passed countercurrent to the downflowing residue. As the material flows through the reactor, it passes successively through stages of drying, reduction, and oxidation; at the bottom, ash is removed in molten form at a temperature of about 3,000° F. Crude gas containing a large amount of moisture leaves the top at a temperature of about 200° F.

Development work was initiated by Union Carbide in 1970, in a pilot plant sized for a feed rate of 2.5 ODT/D (ovendry tons per day) of garbage. In 1974, a demonstration plant using a 10-foot-diameter reactor, having a capacity of 150 ODT/D of garbage, was put into operation. Scaleup of the reactor to this level resulted in a significant decrease of conversion efficiency, as evidenced by an increase in carbon dioxide and hydrocarbon levels in the raw gas.

An important factor in the performance of any moving bed reactor is the stability of the bed. Stability apparently decreases with increasing diameter. The diameter limitation has been demonstrated in the gasification of coal by the Lurgi Process. Lurgi has succeeded in operating a reactor 11.7 feet (ft) in diameter, but failed to put into operation a reactor of 13.7 ft. This casts some doubt on the possibility of further scaleup of the Purox reactor beyond 12 ft, even if its performance on wood waste was demonstrated to be superior to that of garbage.

Moore-Canada

Moore-Canada of Richmond, British Columbia has developed, over the past two years, a moving bed reactor for producing a low Btu gas from "as-is" wood waste. In contrast to Purox, the Moore reactor relies on the use of air as the oxidizing medium. Because of the high nitrogen content, the raw gas has a heating value of about 180 Btu per standard cubic foot (scf), in contrast to that of the heating value of the Purox unit of 350 Btu/scf.

^{3/} Anderson, J. E. 1973. Solid refuse disposal process and apparatus. Patent No. 3,729,298. April 24.

Currently a semi-works unit is in operation. This unit has a 5.5-ft-diameter gasifier with a capacity of about 18 ODT/D of wood waste. A commercial installation is being put into operation in mid-1976. This facility utilizes two 9.5-ft-diameter reactors, each capable of processing 60 ODT/D of hogged wood waste.

Operation of the Moore reactor is similar to Purox in that the feed material enters at the top and the wood ash is discharged from the bottom. However, because air rather than oxygen is used, the maximum temperature of the oxidation (lower) zone is only about 2,200° F; waste is discharged as a solid in a granular form rather than as a molten slag. Pressure at the base of the reactor is approximately 6-8 lb/in.²_g and at the top 2-3 lb/in.²_g. The raw gas leaves the reactor at a temperature of 160° or 180° F. By adding steam to the air, the hydrogen content of the crude gas from the Moore reactor-gasifier is increased from 8-10 percent to 18-22 percent.

Other Gasifier Designs

Battelle.--The Battelle Pacific Northwest Laboratories carried out a 1-year pilot plant study on the partial oxidation of municipal refuse in a 3-ft (inside diameter) moving bed reactor pilot plant^{4/}. This study also included partial oxidation of wood chips using air and steam, with results that approximated those reported by Moore-Canada.

Thermex.--A 50 ODT/D demonstration plant for the gasification of wood waste has been put into operation in Edmonton, Alberta, Canada, by Alberta Industrial Development, Ltd. Under its present mode of operation, it produces a char and a low-Btu gas, but it is understood that it can be designed to operate without forming char. The gasifier is a fluidized-bed type requiring that the wood waste feed be hammermilled to less than 2-in. particle size. No data are available at this time regarding gas composition.

Copeland.--The Copeland organization has built, over the past 15 years, a number of fluidized-bed reactors for the pulp industry for disposal of the organic matter in waste liquor. Such a unit would be able to accept "as-is" wood waste and sludge, but its applicability to partial oxidation for syngas has not been investigated.

Lurgi.--The Lurgi reactor is designed to gasify coal with oxygen and steam at 300-400 lb/in.²_g^{5/}. It can handle only noncaking type coal, utilizing a particle size range from 3/8 to 2 in. At this time, no attempt has been made to process wood waste in a Lurgi reactor. The reactor requires relatively uniform particle size and would not be expected to handle wood waste.

^{4/} Hammond, V. L. 1972. Pyrolysis-incineration process for solid waste disposal. Battelle Pacific Northwest Laboratories, Richland, Wash. December.

^{5/} Maddox, R. N., ed. 1975. Energy Communications 1(5):433-494.

Winkler.--The Winkler unit is a fluidized bed coal gasifier operating at or near atmospheric pressure^{5/}. These gasifiers are typically 18 ft in diameter and operate at a temperature of about 2,200° F. Coal fed to the Winkler is ground to less than 1/4 in. No attempt has been made to apply the Winkler gasifier to wood waste, nor does it appear to offer promise in this area since particle size is limiting.

Koppers-Totzek.--These units process pulverized coal with steam and oxygen under slagging conditions at atmospheric pressure at temperatures up to 3,500° F^{5/}. Although about 16 Koppers-Totzek installations have been built, employing a total of about 40 gasifiers, this type gasifier is not deemed practical for the handling of wood waste because of requirements for finely ground feed.

On the basis of currently available data, the Moore-Canada gasification system was judged to be the most promising and, therefore, was adopted as the basis for this study. The material balance for the Moore-Canada is shown in tables 2 and 3.

GAS PURIFICATION

Crude gas from partial oxidation units is processed to remove water vapor, tars, organics, hydrocarbons, nitrogen, and CO₂. The clean gas, containing primarily H₂ and CO, is then processed in a shift reactor to react part of the CO to form additional H₂, so the final gas contains the proper ratio of 2:1 of H₂ and CO. In the shift reactor, additional CO₂ is formed, thus making it necessary to again scrub the gas before the synthesis reactor.

Crude gas from the gasifiers passes upward in the single cooler-absorber-scrubber, cooling the gas from about 180° to 90° F in three stages of contacting (fig. 1, step 2). In the lower two stages, cooled, recirculated liquor streams contact the crude gas. In the upper stage, reclaimed water condensate is used to complete the removal of organic compounds such as acetic acid.

Because the moisture condensed from the crude gas (roughly equal in weight to the dry wood substance entering the system) contains about 2 percent of soluble organics, it is necessary to clean the stream for environmental reasons. One technique for organics recovery is with a suitable solvent such as methyl ethyl ketone in a liquid-liquid multiple-stage extraction operation. The extract or light density phase is processed in an extraction tower to recover the solvent overhead and the organic-rich material from the bottom. The heavy density raffinate phase is processed in a raffinate stripper to recover that portion of the solvent dissolving in the water phase. From the bottom of the raffinate stripper, the effluent is essentially a water product of low biochemical oxygen demand (BOD). The organic product

Table 2.--Material balance, feed to reactor-gasifier

Unit	Pounds per oven-dry ton of wood	Pounds per hour
<u>Wood waste</u>		
62.5 ODT/h		
125,000 lb/h		
1,500 ODT/D		
Carbon	1,016	63,500
Hydrogen	126	7,880
Oxygen	796	49,740
Nitrogen	2	130
Ash	60	3,750
Moisture	<u>2,000</u> 4,000	<u>125,000</u> 250,000
<u>Air</u>		
Oxygen	750	46,875
Nitrogen	2,475	154,570
Water	<u>55</u> 3,280	<u>3,455</u> 204,900
<u>Steam</u>		
Water	333	<u>20,800</u>
<u>Total In</u>		475,700

Table 3.--Material balance, products from reactor-gasifier

	MW	Mol/h	Lb/h
<u>Crude gas</u> ^{1/}			
Hydrogen	2	2,662	5,324
Carbon monoxide	28	3,325	98,100
Carbon dioxide	44	1,237	54,430
Methane	16	363	5,810
Hydrocarbon--Average	41	131	5,370
Nitrogen	28	5,525	154,700
Oxygen	32	69	2,206
Moisture	18	<u>438</u>	<u>7,885</u>
		13,750	328,825
<u>Ash</u>			3,750
<u>Condensate--water layer</u>			
Organic compounds			3,600
Water			<u>139,525</u>
			143,125
<u>Total Out</u>			475,700

1/ Following partial condensation and separation of condensate.

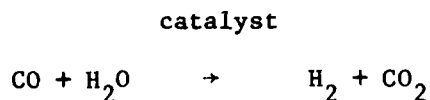
from the extraction tower may be used as a fuel in the boiler. Alternatively, it may be economically feasible to separate the stream into its components, mostly acetic acid, for byproduct value.

The cooled and partially purified gas is then compressed to about 100 lb/in.²g (fig. 1, step 3) and treated in a two-stage system to remove carbon dioxide. In the first stage, a hot potassium carbonate system is used to reduce CO₂ content to about 300 parts per million (ppm) (fig. 1, step 4). In the second stage, it is reduced to about 50 ppm using monoethanolamine as a scrubbing agent (fig. 1, step 5). A single-stage system of monoethanolamine could be used, but at the expense of greatly increased steam consumption.

The clean compressed gas passes to a cryogenic system (fig. 1, step 6). In a series of switching exchangers, the residual CO₂ and water vapor are removed to prevent freezeup in the downstream exchangers and distillation towers. Next, methane and hydrocarbons are removed. Cryogenic distillation is used to separate CO from nitrogen; the liquid nitrogen leaving the system is used to precool the incoming gas. The purified product gas is a mixture of carbon monoxide and hydrogen. However, it requires further processing because it is not in the ratio of 2:1 of H₂ and CO required for syngas to produce methanol.

SHIFT REACTION

Following cryogenic separation of the "inerts" the gas is compressed to 400 lb/in.²g for shift conversion. A portion of the CO reacts with water vapor in the presence of an iron catalyst to form additional hydrogen (fig. 1, step 8), to the extent that the final gas contains the required 2 parts of hydrogen to 1 part of carbon monoxide. The following reaction takes place in the shift reactor:



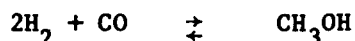
Exothermic Reaction

590 Btu/lb CO

Because the shift reaction produces carbon dioxide, it is necessary to utilize the hot potassium carbonate absorption system (fig. 1, step 9) which removes about 97 percent of the carbon dioxide formed during the shift reaction.

The synthesis gas is now compressed to a pressure ranging from 1,500 to 4,000 lb/in.²g and fed into the methanol synthesis reactor. In the reactor, approximately 95 percent of the gas is converted to methanol, the balance passing as inerts to the boiler. The reaction is as follows:

catalyst



Exothermic Reaction

1,200 Btu/lb CO

Two processes are available for synthesis of methanol, the Vulcan process using a zinc-chrome catalyst operating at pressures ranging from about 2,000 to 4,000 lb/in.²g and the more recent ICI copper catalyst process operating at pressures ranging from 1,000 to 2,000 lb/in.²g. A key factor in setting the system pressure for either process is the purity of the feed. With increasing amounts of impurities, the system requires higher pressure to minimize "inerts" leaving the system.

The crude methanol product from the synthesis reactor passes to a distillation train for separation of the light ends and higher alcohols from the methanol product. The mixture of light ends and higher alcohols is used as a fuel in the boiler. Catalyst life is expected to be 6 years for methanol synthesis and 2 to 3 years for the shift reactor.

PLANT SIZE

In a chemical processing facility, production cost depends mainly on capital investment and raw material cost. The most common means for reducing unit costs is to build a high-capacity facility because investment for scaleup generally increases as production increases by a 0.6 factor. In recent years, the trend in the synthetic methanol industry has been to increase plant sizes from about 50 million gpy to 200 million gpy. Twelve plants in the U.S. can produce 1.2 billion gpy of methanol, as shown in table 4.

For the Forest Service engineering study, it was decided to size the methanol from wood-waste plant at a capacity of 50 million gpy, comparable to the small size plants making methanol from natural gas. The investment for this size facility can be scaled up in accordance with standard procedures used by engineering organizations for chemical processing plants.

The Forest Service has estimated that the cost of collecting and transporting wood waste to a central location for processing would range between \$15

Table 4.—Methanol production

Capacity (million gpy)	Number plants	Total (million gpy)
22	1	22
50	3	150
80	1	80
100	4	400
160	1	160
200	1	200
230	1	<u>230</u>
Total U.S. capacity		1,242

Table 5.—Comparison of fuel values

	Gross heating value	Combustion efficiency	Fuel value
		<u>Pct</u>	
Wood waste	18 million Btu/ODT	<u>1</u> /66	\$24.00/ODT
Coal	24 million Btu/ODT	80	\$38.40/ODT
Oil	6 million Btu/bbl	85	\$10.20/bbl
Natural gas	1 million Btu/mcf	87	\$ 1.75/mcf

1/ Based on "as-is" or about 50 percent moisture by weight.

and \$34/ODT. For comparison, the current delivered price for pulpwood ranges between \$40 and \$60/ODT. Aside from its value as a potential source of methanol, wood waste may be used as a source of fuel. Its minimum value would thus seem to be its fuel value relative to more conventional fuels. In the 1975 fuel market, wood waste can compete with other fuels when its price is below \$24/ODT, so that this would set the minimum cost for waste wood utilized in a chemical process. A comparison of wood waste with conventional fuels, assuming a value of \$2/million Btu of net heat recovered is shown in table 5.

ECONOMICS

An estimate of investment and operating costs for a 50 million gpy synthetic methanol plant from wood waste has been developed. To determine the effect of scaleup on cost, an estimate has also been prepared for a facility capable of producing 200 million gpy. These estimates are compared with estimates of investment and operating costs for facilities using natural gas and coal as raw materials. All of these investments are based on facilities utilizing boilers to produce steam to generate electricity and to drive turbines required for compression. Therefore, these plants are self-sufficient, requiring no outside utilities other than cooling water makeup.

Investment

The investment estimate requirement for a 50 million gpy methanol plant using wood waste totals \$64.0 million (1975 dollars). A breakdown of this estimate into key sections is given in table 6.

This estimate covers a complete "grass roots" facility, including off-site utilities, wood yard handling facilities, finished product storage, and office and laboratory buildings. It includes a contingency of 25 percent and working capital of 5 percent. No provision has been made for expected escalation in cost of equipment and construction labor.

Operating Costs

An estimate of operating costs for the 50 million gpy methanol plant is listed in table 7. Production costs include fixed costs, raw material, labor, and overhead. Fixed costs are based on an allowance of 8 percent for depreciation, 4 percent for maintenance (including labor and material) and 2 percent for local taxes and insurance. Profit is based on a nominal return of 30 percent on investment, equal to 15 percent after Federal income tax.

**Table 6.--Investment estimate for wood waste methanol
plant of 50 million gpy**

Description	Investment	
Wood yard	\$ 3,010,000	
Gasifier	4,000,000	
Cooling/scrubbing	802,000	
Organic recovery	2,256,000	
Primary compression	1,597,000	
CO ₂ removal	1,704,000	
Cryogenic	4,000,000	
MeOH synthesis	7,330,000	
Offsites		
Steam generation	\$7,200,000	
Electrical generation	1,587,000	
Water treating	840,000	
Cooling tower	1,727,000	
Storage and shipping	1,152,000	
Fire protection	<u>250,000</u>	
		12,756,000
Distribution		
Steam	\$ 832,000	
Water	1,360,000	
Electric	<u>875,000</u>	
		3,067,000
Buildings/structure		
Administration	\$ 362,000	
Laboratory	106,000	
Maintenance	348,000	
Control house	104,000	
Compressor building	105,000	
Utility building	<u>300,000</u>	
		1,370,000
Site development		
Clearing, grading	\$ 75,000	
Roadway, parking	276,000	
Fencing	36,000	
Railroad siding	80,000	
Sewer facilities	<u>40,000</u>	
		507,000
Engineering and license fee	<u>\$6,360,000</u>	
Estimate subtotal		\$48,759,000
Contingency--25 percent		<u>12,191,000</u>
		\$60,950,000
Working capital--5 percent		<u>3,050,000</u>
Total investment		\$64,000,000

Table 7.--Production cost estimate and product price, wood
waste methanol plant of 50 million gpy

	Annual \$ million	\$/Gal	Percent
<u>Fixed costs</u>			
Depreciation 8 pct investment	\$5.12		
Maintenance 4 pct investment	2.56		
Taxes and insurance 2 pct investment	<u>1.28</u>		
	\$ 8.96	\$0.179	18.7
<u>Raw material</u>			
Wood waste--1,500 T/D at \$34/ODT	17.36	0.347	36.2
<u>Labor</u>			
Operators--10 stations at \$80,000/yr	0.80		
Foremen--3 stations at \$100,000/yr	0.30		
Management--at \$100,000/yr	<u>0.10</u>		
	1.20	0.024	2.5
<u>Overhead--100 pct labor</u>	1.20	0.024	2.5
<u>Profit--20 pct of investment before taxes</u>	<u>19.20</u>	<u>0.384</u>	<u>40.1</u>
Total	\$47.92	\$0.958	100.0

At a wood waste cost of \$34/ODT, the selling price of methanol is estimated at \$0.96/gal. At a wood waste cost of \$15/ODT, the delivered price is \$0.77/gal. The 1975 price of methanol was \$0.38/gal, Gulf Coast, tank car lots.

Comparison With Natural Gas and Coal

Because of the simplicity of the conversion of natural gas to methanol, the investment costs for such a plant is about one-third that of a comparable wood waste facility. Also, conversion efficiency of natural gas to methanol is significantly greater than that of wood waste. It takes 150 ft³ of natural gas (containing more than 95 percent methane) or 4.9 lb to make 1 gallon of methanol. A comparison of efficiency of conversion of natural gas, coal, and wood waste is shown in figure 2.

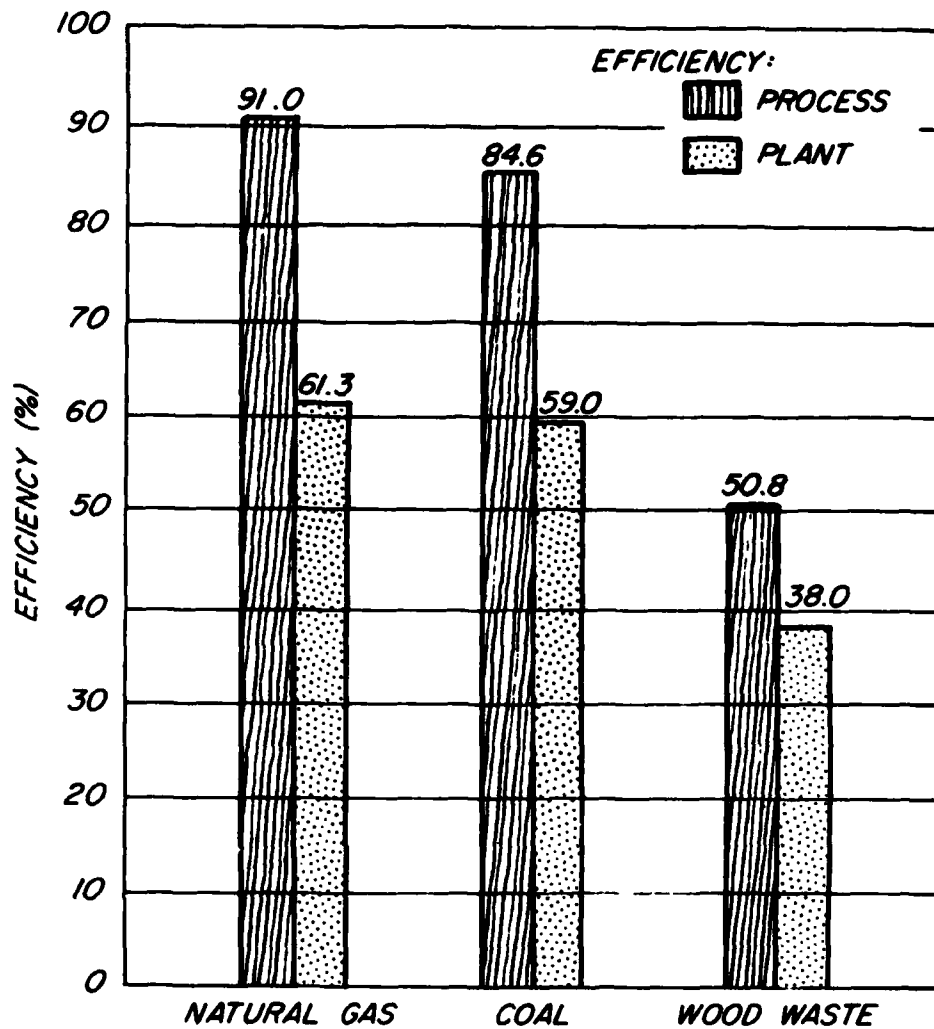
Conversion of coal to methanol, while considerably more efficient than that of waste wood, involves more processing facilities because of the greater amount of ash and sulfur (wood has no sulfur). Coal conversion to syngas is more efficient because it has a higher carbon content and less oxygen than wood. Comparison of investment requirements for a 50 and 200 million gpy methanol facility for each of these raw materials is shown in figure 3.

The raw material input for three types of methanol synthesis plants is shown in table 8.

It is of interest to note that the 50 million gpy facility utilizing 1500 ODT/D wood waste is comparable to a pulp mill producing about 800 T/D of finished pulp. The 200 million gpy facility would be comparable to 3,300 T/D production of pulp.

Methanol selling price was calculated on a basis of 30 percent annual profit on investment, 15 percent after Federal income tax. Production costs, gross profit, and net profit for each type of facility is shown in table 9.

A comparison of the delivered price of methanol as a function of the raw material costs and plant size for these three methanol facilities is shown in figure 4.



Heating value:

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Natural gas--1,000 Btu/cubic foot

Coal, New Mexico coal with 19 percent ash content--8,600 Btu/lb

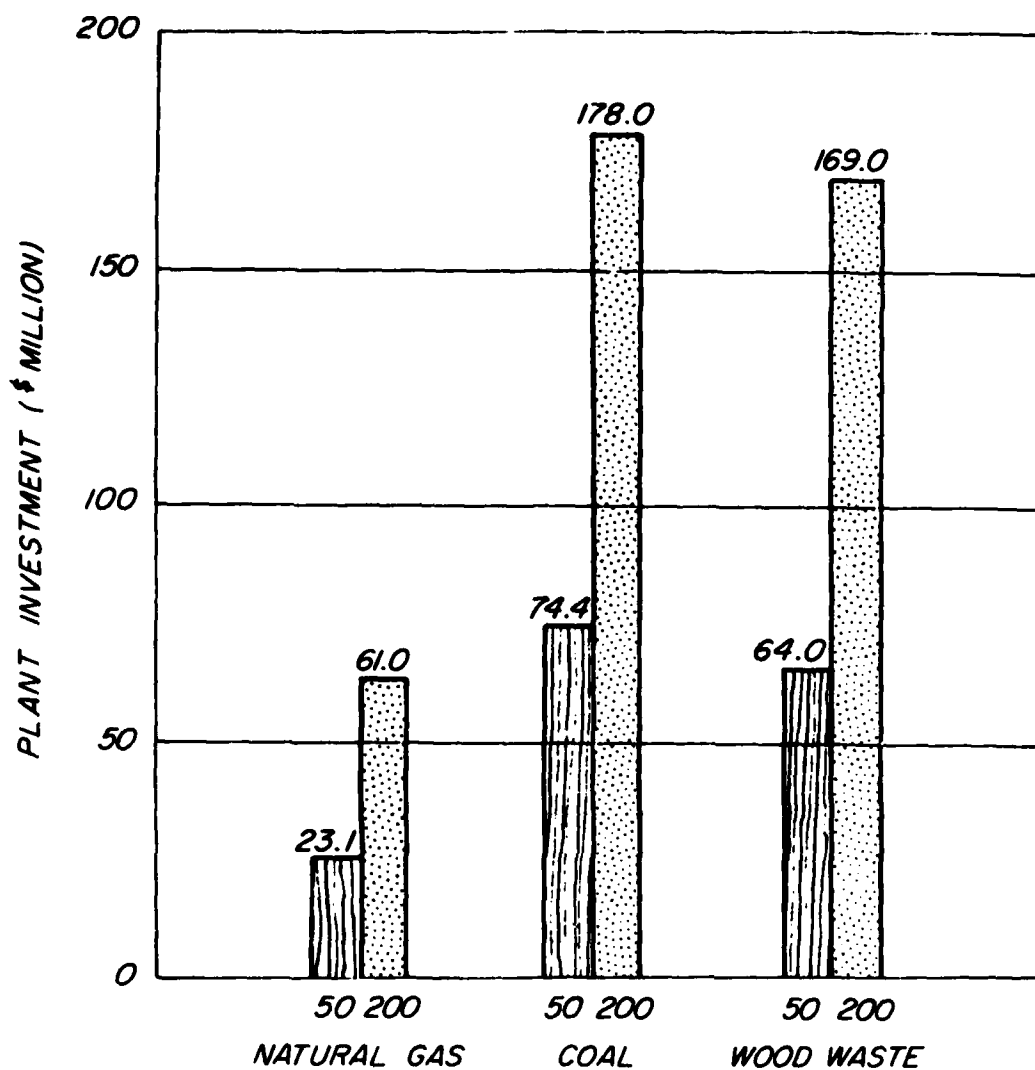
Wood waste, Douglas-Fir with 25 percent bark content--9,000 Btu/lb

Efficiency:

Process efficiency--Heating value of methanol as a percent of heating value of process feed.

Plant efficiency--Heat value of methanol as a percent of total energy input into plant.

Figure 2.--Methanol Synthesis Conversion Efficiency for Natural Gas, Coal, and Wood Waste



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Investment Estimate

Based on 1975 costs
Includes 25% contingency
No escalation included

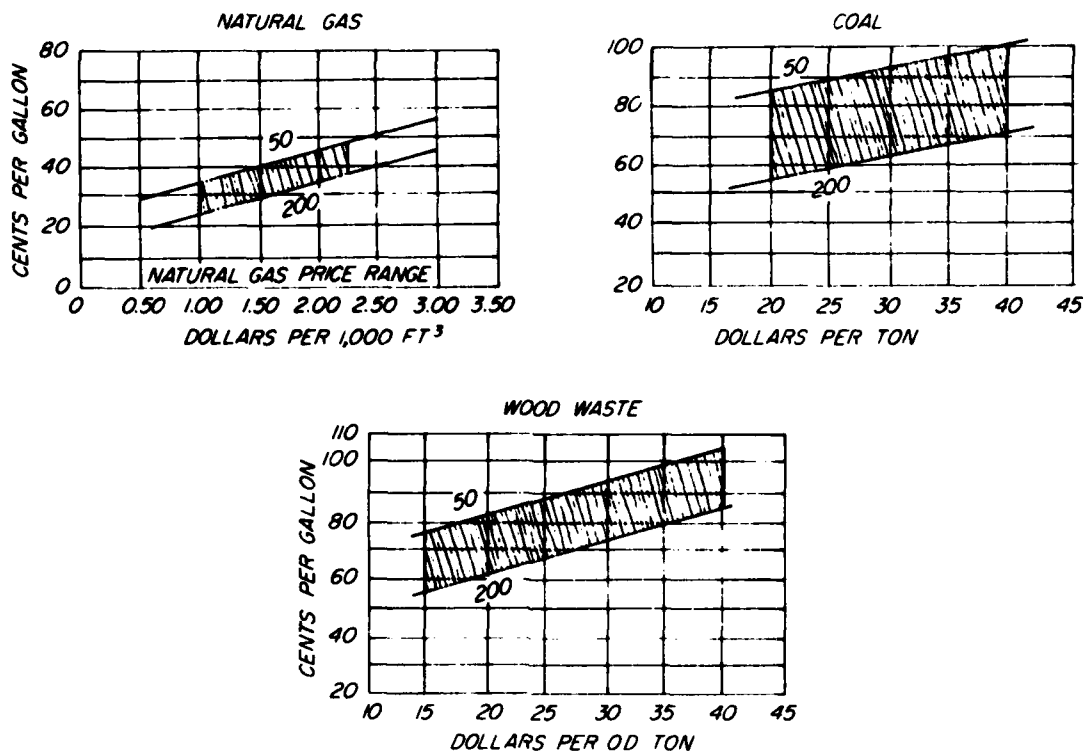
Figure 3.--Methanol Synthesis Plant Investment for Plants of 50 and 200 Million Gallons Per Year Facilities (Additional cost for coal vs. wood due to pressurized system, increased steam requirements, and desulfurization equipment.)

Table 8.--Raw material input for methanol plants

	50 million gpy	200 million gpy
Natural gas	16.3 million cfd	65.2 million cfd
Coal	1,380 ODT/D	5,520 ODT/D
Wood waste	1,500 ODT/D	6,000 ODT/D

Table 9.--Methanol selling price

	Cents per gallon			
	Production cost	Gross profit	Net profit	Selling price
<u>50 million gpy</u>				
Natural gas at \$1.75/mcf	32.0	14.0	7.0	46.0
Coal at \$38/ton	53.4	44.6	22.3	98.0
Wood waste at \$34/ODT	59.6	38.4	19.2	98.0
<u>200 million gpy</u>				
Natural gas at \$1.75/mcf	25.8	9.2	4.6	35.0
Coal at \$38/ton	41.4	26.6	13.3	78.0
Wood waste at \$34/ODT	57.8	25.2	12.6	83.0



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<u>Production Costs</u>	<u>Percent Invest.</u>
Depreciation	8
Maintenance	4
Taxes and insurance	2
Profit before taxes	30
After taxes	15

Figure 4.--Methanol 1975 Selling Prices From Natural Gas, Coal, and Wood Waste With Plant Capacities of 50 and 200 Million Gallons Per Year.

U.S. Forest Products Laboratory.

Methanol from wood waste: A technical and economic study, by A. E. Hokanson and Roger M. Rowell. Madison, Wis. For. Prod. Lab., 1977.

21 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. FPL 12)

A methanol-from-wood waste facility with a capacity of 50 million gallons per year requires 1,500 oventry tons of wood waste per day. At a wood waste cost of \$15 per oventry ton, the selling price of the methanol is estimated at \$0.99 per gallon.

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CONCLUSIONS AND RECOMMENDATIONS

It is technically feasible but not economically attractive to produce methanol from wood waste. If the use of natural gas is prohibited for the production of methanol, a possible source for syngas would be additional refinery light-gas streams. If this latter source is insufficient, then coal would offer the most likely source of raw material, particularly for a methanol plant located near or adjacent to a mining operation.

In carrying out the Forest Service technical study on methanol-from-wood waste, known technology was used. A key to improving the efficiency of the process lies in improving the efficiency of the reactor-gasifiers to increase CO and H₂ contents and thereby reduce CO₂ and hydrocarbons.

The most promising reactor-gasifiers for wood gasification are the Moore-Canada and the Union Carbide Purox unit. An experimental development program is recommended for the Moore-Canada unit to attempt to improve its efficiency. It is also recommended that experimental work be carried out on the Purox unit using wood waste. Pressure partial oxidation should be investigated to determine its practicability and efficiency.

A methanol-from-wood waste facility having a capacity of 50 million gpy requires 1,500 ODT/D of wood waste. This is about the same quantity of wood required for a kraft pulp mill producing 800 T/D of pulp. In view of the pulp industry's progress in utilizing lower and lower grade feed materials such as sawdust and some bark, wood waste might be utilized in the near future to produce pulp. Pulp would have a product value about three times that of wood waste converted to methanol.

Upon examining methanol synthesis, one finds that the energy yields are relatively poor; even in the case of natural gas and coal, the final methanol product from natural gas contains about 60 percent of the total energy input into the plant (figure 2). For a wood waste facility, the yield is about 38 percent. That is, the total energy input for a 50 million gpy methanol unit utilizing 1,500 ODT/D amounts to 1,125 million Btu/h and the final methanol product has a heat value of 427 million Btu/h (gross basis).

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